AD-A160 782 'METALLIC REGIME OF SILICON INVERSION LAYERS ENERGY LEVELS AND TRANSPORT PROPERTIES'(U) YALE UNIV NEW HAVEN CT DEPT OF APPLIED PHYSICS R G WHEELER 13 JAN 84 1/1

UNCLASSIFIED N00014-76-C-1083 F/G 9/1 NL

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16. SUPPLEMENTARY NOTATION

"Metallic Regime of Silicon Inversion Layers, Energy Levels, and Transport Properties"

17. COSATI CODES		
FIELD	GROUP	SUB. GR.

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)

silicon inversion layers; submicron devices; elastic scattering; inelastic scattering

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

In n-channel silicon inversion layers the small resistance changes with temperature below 4°K have been observed and the physical mechanisms quantified. These mechanisms are a temperature dependent elastic scattering due to dynamic screening, a temperature dependetn electron-electron inelastic scattering which is mostly mitigated by impurities, and the many body effect upon the elastic scattering. In high quality silicon MOSFETs, inelastic diffusion lengths of about 2 μm have been observed, which demonstrated quasi-one dimensional transport processes in submicron devices.

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20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☐	21. ABSTRACT SECURITY CLASSIFICATION: unclassified/unlimited
22a. NAME OF RESPONSIBLE INDIVIDUAL: Dr. George B. Wright	22b. TELEPHONE NUMBER (Include Area Code): (202) 696-4215; 22c. OFFICE SYMBOL: ONR

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NOTE: There are two copies each of the papers cited in section 4 above attached for ONR distribution.

FINAL REPORT

to the

OFFICE OF NAVAL RESEARCH

"Metallic Regime of Silicon Inversion Layers, Energy Levels, and Transport Properties"

15 September 1980 - 14 September 1982

ONR Contract No. N00014-76-C-1083

Robert G. Wheeler
Principal Investigator

Yale University
Section of Applied Physics
P.O. Box 2157
New Haven, Connecticut 06520

13 January 1984

Distribution of this report is unlimited.

Research Summary

This research on silicon inversion layers at low temperatures initially investigated the far infrared absorption and photo response of the subband energy levels associated with the channel electrons. While the description of the photon absorption process was straightforward, the influence of the photoexcited electron upon the photoelectric response was not understood. The major response was photoresistive suggesting a diminished mobility of the photoelectron. However, under some conditions of temperature and electron density, a photoconductive response was dominant.[1] It was clear at this point that the temperature dependent conductivity processes at low temperatures were not understood. Thus we undertook a series of experiments to define the essential physics of temperature dependent scattering. At about this time there was great activity in the theoretical community concerning the ideas of weak localization, which imply a decreasing conductivity with decreasing temperature.[2]

The ability to fabricate high mobility silicon MOSFETs w $\approx$ 20,000 cm^2/Vsec, was essential to unravel all the contributions to the small temperature effects. Secondly, the theoretical prediction that a magnetoconductance would occur (which removes the localization part of the resistance) proved to be the most important development, for now one could experimentally separate out the localization part.[3] We showed that below 10 K phonons play no part in the observable temperature dependence. This conclusion was reached by observing the existence of a conductivity decrease with temperature whose magnitude was proportional to the number of Coulomb scattering sites, and which decreased nearly linearly with increasing electron density.[4] In collaboration with Dr. F. Stern of IBM, an explanation in terms of a temperature screening was formulated which agrees with the essential aspects of the observation.[5] Following this, one observed a characteristic logarithmic decrease in conductivity as the temperature was decreased. It was pointed out, theoretically, that this temperature signature was insufficient evidence; that many body screening effects produce similar signatures.[3] Concurrent with this observation, the prediction of a strong magnetoconductance was made, whereby with our mobility samples a magnetic field of 100 gauss should produce a conductivity change such as to cancel the effect due to three decades in temperature.[3]

The experiments so suggested were carried out, producing the predicted large magnetoconductance.[6] Using the theory we deduced that there are two inelastic scattering mechanisms: Electron-electron scattering mitigated by impurities giving a dependence upon temperature, and Fermi temperature as $\tau_{ee} \sim (T_F/T)$, which is dominant at the lowest temperatures ($T < 2K$). At low electron densities and higher temperatures ($T > 2k$) the Landau electron-electron scattering is dominant $\tau_{ee} \sim (T_F/T)^2$.[7]

These results were based upon the comparison of the length between inelastic scattering events with a magnetic length $\ell_H^{\ 2} = \hbar/2eB$. In high mobility samples we find ℓ_{in} 1-2 x 10^{-6} meters. This result suggested that a physical scale could be applied to the two dimensional geometries such that this length be greater than the width of the channel. Submicron devices were fabricated which showed that a transition to quasi-one dimensional electron transport occurs when the above scale lengths were satisfied. Here we were able to quantitatively separate the localization, many body and temperature dependent screening parts of the conduction process. The MOSFET system was the first to allow unambiguous observation of localization in one dimension. All previous observations on metal systems can be attributed to only many-body effects.[8] The necessity to have low numbers of Coulomb scattering sites was established as a necessary prerequisite for observation of localization.

These experimental researchers made significant contributions to our understanding of the importance of inelastic scattering in controlling the conductivity of inversion layers. It has also suggested the possibility of spatial quantization experiments, for when the inelastic length is greater than a boundary separation we expect to observe discrete energy levels so implied.

Lastly, a number of experimental projects were failures. In 1978-79 we attempted to observe by Raman scattering techniques the electron subband energy levels in silicon inversion layers. Subsequently in GaAs heterojunctions such energy levels were observed.[9] The important improvement obtained is that in polar materials such as GaAs the necessary matrix elements are about 2 orders of magnitude greater than that estimated for the silicon system.

References

1. C. C. Hu, J. Pearse, K. M. Cham and R. G. Wheeler, Surface Science 73 (1978).
2. E. Abrahams, P. W. Anderson, D. C Licciardello and T. V. Ramakrishnan, Phys. Rev. Lett. 42, 673 (1979).
3. B. L. Altshuler, D. Khmel'nitskii, A. I. Larkin and . P. A. Lee, Phys. Rev. B22 (1980) 5142.
4. K. M. Cham and R. G. Wheeler, Phys. Rev. Lett. 44 (1980).
5. F. Stern, Phys. Rev. Lett. 44, 1469 (1980).
6. R. G. Wheeler, Phys. Rev. B24 (1981).
7. E. Abrahams, P. W. Anderson, P. A. Lee and T. V.Ramakrishnan, Phys. Rev. B 24, 6783 (1981).
8. N. Giordano, Phys. Rev. B 22, 5635 (1980).
9. G. Abstreiter, Surface Sci. 98 (1980) 117.

Personnel Supported Totally or in Part by this Grant

1. Dr. C. C. Hu is employed by International Business Machines at Fishkill. He is engaged in VSLI dipolar circuit fabrication research.
2. Dr. Kit Man Cham is employed by the Hewlett-Packard Corporation in Palo Alto. He is engaged in device modelling for VSLI.
3. Mr. J. Pearse is employed by the Motorola Corporation at their facilities in Arizona. He is a production engineer on memory circuit fabrication.
4. Dr. Atul Goel is employed by the Hewlett-Packard Corporation at Fort Collins, Colorado. He is a research engineer designing the optical processing for submicron VSLI circuits.
5. Dr. K. K. Choi is a post doctoral associate with Professor D. Tsui at Princeton University. He is engaged in studies of localization phenomena in GaAs devices.

Papers Published

1. "Photoconductivity Measurements Related to Intersubband Transitions in Silicon Structures," C. C. Hu, J. Pearse, K.M. Cham and R. G. Wheeler, Surface Science 73 (1978).
2. "Electron-Phonon Interactions in n-Type Silicon Inversion Layers at Low Temperatures," K. M. Cham and R. G. Wheeler, Surface Science 98 (1980).

3. "Temperature-Dependent Resistivities in Silicon Inversion Layers at Low Temperatures," K. M. Cham and R. G. Wheeler, Physical Review Letters 44 (1980).
4. "Magnetoconductance and Weak Localization in Silicon Inversion Layers," R. G. Wheeler, Physical Review B 24 (1981).
5. "Inelastic Electron-Electron Scattering Times in Silicon Inversion Layers," R. G. Wheeler, K. K. Choi and A. Goel, Surface Science 113 (1982).
6. "Localization and Electron-Electron Interaction Effects in Submicron-Width Inversion Layers," R. G. Wheeler, K. K. Choi, A. Goel, R. Wisnieff and D. E. Prober, Physical Review Letters 49 (1982).

Theses Accepted by Yale University

C. C. Hu,"Dual Photoconductivity Effects Induced by the Intersubband Transitions in n-Type Silicon Inversion Layers," 1978.
K. M. Cham, "Transport Properties of n-Type Silicon Inversion Layers in MOSFET Structures at Low Temperatures," 1980.
A. Goel, "Fabrication of Submicron Width MOSFETs for One-Dimensional Weak Localization Studies," 1983.
K. Choi, "Interaction Processes and Transport Properties of One- and Two-Dimensional Electronic Systems," 1984.

APPENDIX 1.

ABSTRACT

DUAL PHOTOCONDUCTIVITY EFFECTS INDUCED BY THE INTERSUBBAND TRANSITIONS IN n-TYPE SILICON INVERSION LAYERS

Chih Chun Hu

Yale University, 1979

When a strong electric field is applied normally to a semiconductor surface, the electron motion perpendicular to the surface is quantized, and a sequence of electric subbands is formed. Intersubband transitions have been observed in absorption, photoconductivity and emission experiments. A discrepancy has been found between the values of the resonant energy for the transitions between the ground subband and the excited subband. The photoconductivity and emission results reported in the literature agree with each other, but not with the absorption data in the literature. It is shown here that the photoconductivity measurements on inversion layer are in one-to-one correspondnece with absorption when these two measurements are done on the same sample.

The physical mechanism of photoconductivity in n-channel MOSFET on (100) surface of silicon is investigated. The photoresponse is a combination of photoresistive intersubband transition, the resonant bolometric heating and a Drude heating background. Drude heating arises from the free carrier absorption in the inversion layer. The other two mechanisms are due to intersubband transition. Photoresistive intersubband transition gives rise to a resistive response because of a low mobility excited state. Resonant bolometric heating and Drude heating give rise to either conductive or resistive response determined by the sign of $\frac{dG}{dT}$.

TRANSPORT PROPERTIES OF n-TYPE SILICON INVERSION LAYERS IN MOSFET STRUCTURES AT LOW TEMPERATURES

A Dissertation

Presented to the Faculty of the Graduate School

of

Yale University

in Candidacy for the Degree of

Doctor of Philosophy

by

Kit Man Cham

December 1980

ABSTRACT

The transport properties of n-type silicon inversion layers in MOSFET structures at liquid helium temperatures have been studied in detail. Precision measurements of the temperature dependence of the resistivity from 1 to 5°K have been made. The temperature dependence was studied as a function of electron density, substrate bias, device quality and device geometry. For electron densities below 2×10^{12} cm^{-2}, the resistivity increases with increasing temperature. This behavior was shown to be primarily due to Coulomb scattering and possibly also due to surface roughness scattering. At electron densities above 6×10^{12} cm^{-2}, the resistivity increases almost logarithmically with decreasing temperature. This is suggested to be due to localization effects or interaction effects in the impurity scattering, depending on the sample quality. It is suggested that for the whole range of electron densities under investigation, the temperature dependence of the resistivity be described by the combination of a linear term and a logarithmic term due to the above mentioned mechanisms.

Electron-phonon interaction has been studied through warm electron effects. The agreement between theory and experiment is unsatisfactory, both quantitatively and qualitatively. Further experiments are suggested to justify the assumptions used in the theory as well as the technique in measuring the electron temperature.

FABRICATION OF SUBMICRON WIDTH MOSFETs FOR
ONE-DIMENSIONAL WEAK LOCALIZATION STUDIES

A Dissertation
Presented to the Faculty of the Graduate School
of
Yale University
in Candidacy for the Degree of
Doctor of Philosophy

by
Atul Goel

February 1983

ABSTRACT

Recent advances in planar fabrication technology have made possible the construction of submicron size features in Metal-Oxide-Semiconductor Field-Effect Transistor devices. A two step process for producing submicron width gates in n-channel MOSFETs is described in this dissertation. The first step uses 1:1 Contact photolithography to produce the macroscopic features of the device. The second step employs 17.4:1 Projection photolithography to fabricate the narrow, microscopic section of the metal gate. This photolithographic technique helps preserve high cryogenic inversion channel mobilities in the device. The MOSFET thus produced, is used for one-dimensional localization studies. Magnetoconductance measurements demonstrate one-dimensional weak localization effects in the narrow section of the inversion channel, establishing close agreement with theoretical predictions. The results of inversion channel resistance versus temperature experiments cannot be explained by current one-dimensional weak localization theory alone, but do clearly demonstrate that the narrow and wide sections of the channel behave differently. Narrow inversion channel resistance measured against channel electron density at low temperatures, shows a pronounced periodic structure. This periodic structure has been attributed to the quasi-one-dimensional nature of the narrow inversion channel.

ABSTRACT

INTERACTION PROCESSES AND TRANSPORT PROPERTIES OF ONE-
AND TWO-DIMENSIONAL ELECTRONIC SYSTEMS

KWONG-KIT CHOI

Yale University

1984

This work is devoted to the study of the various quantum effects on the interaction processes and the transport properties due to disorder, with a specific electron system. This electron system is created in an electronic device called MOSFET (Metal-Oxide-Semiconductor-Field-Effect-Transistor). The effect of the size of the gate is considered. The theory of localization is described in detail. The electron-electron scattering rate for wide and narrow gate geometries in clean and disordered samples is formulated theoretically and is verified by experiments. The 2-dimensional localization theory is extended to the 1-dimensional case, and has been observed in the narrow channel devices. The 1-dimensional magnetoconductance effect has been observed.

In this work, it has been verified that the linear temperature dependence of the resistivity below 10 K, before the localization effect becomes important, is due to the momentum nonconserving nature of the electron-electron interaction in disordered media.

13 January 1984

Ms. Teri Bennett
Grant and Contract Admin.
107 HGS

Dear Ms. Bennett:

Per your note of December 21, 1983 to me requesting my final patent report and final narrative report in reference to ONR contract number N00014-76-C-1084, enclosed please find all the requested material. We are enclosing seven copies of the final report (2 for your office and 5 for ONR), one copy of the patent report form, and two copies of each paper published (which should be sent to ONR).

Please send the final report to:

Dr. George B. Wright
Code 414
Office of Naval Research
800 Quincy Street
Arlington, VA 22217

Thank you for your help.

Sincerely,

Robert G. Wheeler
Professor and Chairman

RGW:jvm
Enclosures

14 November 1979

Dr. George Wright
Department of the Navy
Office of Naval Research
Arlington, VA 22217

Dear George:

Please find enclosed a page for the Program Summary. I am also enclosing a copy of a letter from Dr. Balk which comments indirectly on our work.

In order to prove the two dimensional phonon system idea, we are attempting to measure resistivities to 009°K. This has slowed things up until we were able to significantly modify the cryostat and pumping system. It now seems to work; hopefully in the next few weeks we will be able to get accurate data in order to decide unambiguously between T^5 and T^4.

May I thank you for your continuing interest and support in our research.

Very sincerely yours,

Robert G. Wheeler

RGW:jvm
Enclosure

N00014-76-C-1083, Yale University, "The Metallic Regime of Silicon Inversion Layers--Energy Levels and Transport Processes," Robert G. Wheeler, (203) 436-4275.

The general aim of this research is to characterize the physics of the two-dimensional gas as embodied in the inversion layer of silicon field effect transistors. Our particular interest is centered upon elucidation of the electron-phonon coupling. There are a large number of experiments including warm electron effects, photoconductivity, and indeed mobility at low temperatures, which depend critically upon the detailed mechanism of energy relaxation.

Progress: During the current year we have made an extended series of warm electron experiments which when analyzed in terms of three-dimensional phonons has led to inconsistencies in terms of theoretical expectations. We have taken the view that these results are consistent with a two-dimensional phonon system. With this conjecture we are currently completing a series of mobility measurements carried down to .9°K in order to confirm a T^4 dependence, a signature consistent with a two-dimensional phonon system (T^5 is consistent with a three-dimensional system). Upon completion of these experiments, we will turn to the warm electron system. Here we desire to fabricate devices which will allow us to determine the characteristic mean-free paths of phonons as limited by the electron-phonon system. It is our goal to be able to describe the spatial form of the phonons which interact with the electron gas.

Recent Publications:

"Photoconductivity Measurements Related to Intersubband Transitions in Silicon MOSFET Structures," C.C. Hu, J. Pearse, K.M. Cham, and R.G. Wheeler, Surface Science 73, 207 (1978).

"Electron-Phonon Interactions in n-type Silicon Inversion Layers at Low Temperatures," K.M. Cham and R.G. Wheeler, Proceedings of the Third International Conference on Electronic Properties of Two-Dimensional Systems, 236 (1979).

REPORT OF INVENTIONS AND SUBCONTRACTS

(Pursuant to "Patent Rights" Contract Clause) (See Instructions on Reverse Side)

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1. NAME OF CONTRACTOR

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Yale University
1504A Yale Station - 108 HGS
New Haven, Connecticut 06520

2. CONTRACT NUMBER
N00014-76-C-1083

3. TYPE OF REPORT (Check one)
a. INTERIM XX b. FINAL

SECTION I - INVENTIONS ("Subject Inventions")

(If "None," so state)

INVENTOR(S)	(ii) TITLE OF INVENTION	(iii) CONTRACTOR DISCLOSURE IDENTIFICATION NUMBER OR PATENT APPLICATION SERIAL NUMBER	(iv) CONTRACTOR ELECTS TO FILE U.S. PATENT APPLICATION YES	NO	(v) CONFIRMATORY LICENSE OR ASSIGNMENT FORWARDED TO CONTRACTING OFFICER YES	NO
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IN REPLY REFER TO

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Ser 1114/1063
NR 372-050

SEP 24 [illegible]

Dr. Robert G. Wheeler
Yale University
Dept. of Engineering and Applied Science
New Haven, CT 06520

Dear Dr. Wheeler:

The Defense Documentation Center has requested a copy of all technical reports generated on contract N00014-76-C-1083, NR 318-050, including the final report.

It is requested that you supply the Defense Documentation Center with copies of these reports as soon as possible.

Defense Logistics Agency
Defense Documentation Center
Cameron Station
Alexandria, Virginia 22314

Sincerely,

Kristl Hathaway

Dr. Kristl B. Hathaway
Scientific Officer

85 10 07 036

PERSONNEL: (10-1-80 to 9-30-81)

Faculty:	Professor Robert G. Wheeler		1 month summer
Post Doc:	None		
Research Sci.:	Stanley Mroczkowski (Crystal Grower/ Chemist)		20% time 12 months
Graduate Student:	Name	Academic Year	Summer
	Kwong K. Choi	50% @ $425/mo.	100% @ $425/mo.
	Robert Wisnieff	50% @ $440/mo.	100% @ $500/mo.

PROPOSED RESEARCH: (For any planned renewal or if to be continued beyond 10/1/81)

The magnetoconductance provides a new tool to measure both band structure and electron temperature. To date only hot electron phonemena have allowed us to investigate electron-phonon interaction. Here the temperature dependence of the amplitude of the Shubnikov-deHaas oscillations have been the only electron thermometer. In all cases, these results have been at least one order of magnitude different than predicted by theory for electron-phonon interactions. Thus with a new electron thermometer we will again attempt to investigate the electron-phonon interaction in inversion layers.

At the same time we now believe that we have sufficient understanding of the scattering processes and experience with device technology to investigate the design of a low temperature MOSFET amplifier which would have an equivalent noise voltage of less than 10^{-9} volts/Hz. Should this prove successful, a number of new experiments on noise at temperatures below 1°K would be possible.

10 September 1981

Dr. George Wright
Department of the Navy
Office of Naval Research
Arlington, VA 22217

Dear George:

I enclose a copy of the Progress Summary sent to R. J. Collins. As I understand your comments to me of about a year ago, you expect that this is the last year of funding for this grant.

As you will notice, I now believe it may be possible to design and fabricate a MOSFET operating at 1.5°K to have a noise somewhat less than 10^{99} volts/Hz, wihh an input capacitance around 10^{-11} Farads. I need such a device to attempt to measure the noise of MOSFETs as a function of frequency at very low temperatures. This may be a way to observe the electron-phonon scattering rate. Over the next six weeks I will be writing up my thoughts on this matter. Might I ask you if from your vantage point there might be interest in such a device elsewhere? I know of course of the interest of the astronomy community.

It was good to see you in New London. My best personal regards,

Sincerely,

Robert G. Wheeler

RGW:jvm
Enclosure

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
ARLINGTON, VIRGINIA 22217

IN REPLY REFER TO
414:RJC:cab
26 AUG 81

Professor R. G. Wheeler
Yale University
Department of Engineering and
Applied Science
New Haven, Connecticut 06520

Dear Contractor:

For several years the Electronics Division has been summarized in an annual volume. This document serves many purposes, e.g., an internal scientific justification of our program, a guide in outlining future programs, a concise summary to explain the programs, etc. In the past, the preparation of this volume has often required the ONR scientist responsible for your contract to digest your reports, prepare a publication list and ultimately proofread the report. To minimize the overall effort this year we are enlisting your help as the best person to summarize your progress and plans.

An additional use of the summary will be new this year. As a part of our funding process a description of the project statement of the future work and a summary of the past year is required for any renewal or continuing contract. Your inputs will be used to meet this requirement. The timing of this response reflects this use.

The document will be assembled here at ONR with an introduction and overview and each contractor will be supplying his own data. In order to have a document meeting the needs without retyping, you are asked to conform exactly to the "form" requested and the example given and to use the paper enclosed. Your submission will be photolithographically reproduced. If possible, use "letter gothic type"; your secretary will be familiar with this "12-pitch type" typewriter element.

The period to be covered should be October 1, 1980 to September 1, 1981. This period need-not and (in general will not) correspond to your actual contract dates.

The schedule allows us only a bare minimum of time for assembling and printing the submitted information before our deadline.

If you would like a copy of the collected reports from the Electronics Division contractors, indicate so by enclosing a note with your return.

Your cooperation is most urgently needed and will be certainly appreciated.

Sincerely yours,

R. J. Collins

R. J. COLLINS (Acting)
Electronics Division

PLEASE RETURN BY SEPTEMBER 11, 1981

TITLE: Metallic Regime of Silicon Inversion Layers - Energy Levels and Transport Properties

PRINCIPAL INVESTIGATOR: Robert G. Wheeler

LOCATION: Yale University
Applied Physics
401 Becton Center
P.O. Box 2157
New Haven, CT 06520

TELEPHONE: (203) 436-4275

NR#: 318-050 CONTRACT #: N00014-76-C-1083

OBJECTIVE: The basic objective is to characterize the physics of the two-dimensional electron gas as embodied in the inversion layer of silicon field-effect transistors.

APPROACH: High mobility field-effect transistors of special geometry have been fabricated to measure the temperature dependent conductivity and magnetoconductance. These dependencies are being used to understand Coulomb scattering, surface roughness scattering, electron-phonon scattering, and localization phenomena which control the transport mechanisms.

PROGRESS: (During the period 10/1/80 - 9/30/81): Temperature dependent conductivities in the liquid helium range have been measured on a variety of devices where the number of Coulomb centers varied by about a factor of ten. One observes and identifies a decreasing conductivity with increasing temperature proportional to temperature due to changes in the dynamic screening. Superimposed on this temperature dependence is a logarithm increase in conductivity as temperature increases due to localization. Application of very small magnetic fields of the order of 40 gauss at 1°K removes this localization resistance. Using current localization theory one is able to extract the inelastic scattering rate by comparison of the inelastic diffusion length with the Landau radius. Lengths of the order of 10^{-6} meters corresponding to inelastic scattering times of $\sim 10^{-10}$ are observed. These rates and their temperature dependencies are characteristic of electron-electron scattering modified by the presence of impurities. Dramatic reduction in inelastic scattering rates is observed when the band structure of the system is modified by population of other valleys.

PUBLICATIONS: (10/1/80 - 9/30/81)

This work will be published in the October 15, 1981 issue of Physical Review B. Extensions to the cases where substrate bias is applied were reported upon at the 4th International Conference of Electronic Properties of Two-Dimensional Systems, August 24-28, 1981, New London, New Hampshire, and will be published in a spring issue of Surface Science.

INSTRUCTIONS

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Professor R. G. Wheeler

YOUR CONTRACT NUMBER IS N00014-76-C-1083

YOUR NR NUMBER IS 318-050

SAMPLE

PAGE 2

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PERSONNEL: (10-1-81 to 9-30-80)

Faculty:	Professor John Brown	5% Academic 1 month summer
Post Doc:	John Smith	100% time 12 months
Research Sci/ Engineer:	None	

Graduate Student:	Name	Academic Year	Summer
	J. Janer	50% @ 600/mo	100% @ $850
	M. Louis	50% @ 600/mo	

PROPOSED RESEARCH: (For any planned renewal or if to be continued beyond 10/1/81)

The infrared-infrared double resonance system will be completed and used for picosecond time resolved infrared spectroscopy of polyatomic molecules with high vibrational excitation.

The visible-infrared double pulse experiments, which have been used successfully on NO_2, will be extended to other molecules, such as biacetyl, which exhibit fluorescence in the excited electronic state with strong vibrational mixing. The antistokes fluorescence will be measured as a function of the frequencies of the exciting visible and infrared pulse, and as a function of the intensity and time delay of the latter with respect to the visible pulse.

The technology of short CO_2 laser pulse generation will be advanced to pulse durations less than 30 picoseconds. A high pressure CO_2 amplifier which has the necessary bandwidth to amplify short pulses, has been purchased under a generous NSF capital equipment grant. It is proposed to use them in the direct amplifier mode as well as injection modelocking. The injection modelocking may permit the generation of CO_2 laser pulses shorter than 10 picoseconds.

SAMPLE

TITLE: Laser Radiation Interactions

PRINCIPAL INVESTIGATOR: John Brown

LOCATION: State University
Department of Science
Riverside, Maine 09876

TELEPHONE: (876) 432-1098

NR#: 372-999 CONTRACT#: N00014-80-C-9999

OBJECTIVE: The basic objective is to study the interaction of short gas laser pulses with plasmas and molecular gases and to advance the technology of short infrared pulses.

APPROACH: TEA CO_2 lasers are used in conjunction with a plasma shutter and a CO_2 absorption cell to provide a free induction pulse with a fast rise time. The pulse is amplified in a TEA CO_2 amplifier to provide a 10.6 μm pulse with a duration as short as 30 picoseconds. This limit may be reduced further by amplifiers operating at higher CO_2 pressures.

The short intense pulses of infrared radiation are used to prepare molecules in states of high vibrational excitation. The pulses are also used to probe excited molecules and to probe gaseous plasmas on a picosecond time scale.

PROGRESS: (During the period 10/1/78 - 9/30/79): In the laser-plasma area the short CO_2 laser pulses have been synchronized with the density step in an electrothermal shock tube. The laser plasma interaction at the preformed density step is studied by means of a miniature β-ray spectrometer which monitors the resonance accelerated electrons. The β-ray spectrometer feeds into a unique multichannel electron collector formed from a circuit board with a lithographed set of collection pads etched into it. The multichannel electron collector is time-multiplexed to display an entire electron spectrum on an oscilloscope photograph in a single shot.

The absolute energy spectrum of electrons in a laser plasma interaction was measured. The spectrum is surprisingly "hard" with a temperature of 40 keV and measureable electron current at energies over 100 keV. This work will be published shortly.

In the area of infrared multiphoton pumping of polyatomic molecules, there are three avenues of exporation: infrared-infrared double resonance, infrared-visible resonance, and the direct monitoring of energy deposition and chemical yield.

We have published (1) a complete summary of our energy deposition and chemical yield work on SF_6 multiphoton pumping. This work is continuing by means of a computerized data gathering system on about a dozen other molecules. In the course of this work a novel deconvolution formula for Gaussian laser beams was found.

The infrared-infrared double resonance involves the synchronization of two independently tunable infrared lasers. It monitors the effect of multiphoton pumping on the overall infrared spectrum. Construction and testing of this equipment is currently progressing.

The infrared-visible double resonance has involved the infrared pumping into an electronically excited state prepared by a visible dye laser. This is followed by observation of the visible fluorescence as affected by the infrared pumping. We have succeeded in observing infrared-visible double resonance in the atmospherically important molecule NO_2. The energy distribution produced by infrared pumping was determined, and the paper has been submitted for publication.

PUBLICATIONS: (10/1/80 - 9/30/81)

1. J. Brown and J. Jones, "Studies in Laser Plasmas", Phy. Rev. A99, 7905 (1980)

2. J. Jones, "Emission Radiation of Laser Plasma", Jour. Quantum Electron, 79, 105, (1981)

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